FULL TITLE
ASP Conference Series, Vol. **VOLUME**, **YEAR OF PUBLICATION**
NAMES OF EDITORS

Comparative analysis of oscillations of a solar quiet region using multi-wavelength observations

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Abstract. We analyze the temporal behavior of a solar quiet region using a set of multi-wavelength observations obtained during a coordinated campaign. The observations were acquired by the ground-based Dutch Open Telescope (DOT), the Michelson Doppler Imager (MDI) on-board SoHO and the UV filters of the Transition Region and Coronal Explorer (TRACE). A large range of height in the solar atmosphere, from the deep photosphere to the upper chromosphere is covered by these instruments. We investigate the oscillation properties of the intensities and velocities in distinct regions of the quiet Sun, i.e. internetwork, bright points (NBP) defining the network boundaries and dark mottles forming a well-defined rosette, as observed by the different instruments and in the different heights. The variations of the intensities and velocities are studied with wavelet analysis. The aim of our work is to find similarities and/or differences in the oscillatory phenomena observed in the different examined regions, as well as comprehensive information on the interaction of the oscillations and the magnetic field.

1. Observations - Results

We use a time series of Hα filtergrams (λ6563 Å, at 5 wavelengths: $\pm$0.35 Å, $\pm$0.7 Å and line center) as well as CaII H (λ3968 Å) and G–band (λ4305 Å) observations of a quiet solar region, obtained by the Dutch Open Telescope (DOT, see Rutten et al. (2004) for details). Subtracting the intensity of red and blue wings we create Doppler Signal (D.S.) maps, at $\pm$0.7 Å and $\pm$0.35 Å from line center, which provide a qualitative measure of the velocity. We also use co–temporal and co–spatial TRACE observations at the UV continua (1550 Å, 1600 Å and 1700 Å). MDI, onboard SoHO provided high resolution line-of-sight magnetograms. The cadence of our observations is 30 s and the duration of the part used here is 30 min. We created 2-D maps of the average global wavelet power (Torrence & Compo (1998)), in three period bands centered at 3, 5 and 7 min (Fig. 1).

In G–Band, NBP's appear bright in the 3 min power maps. In TRACE continua there is suppression of the 3 min and 5 min power above the network, also visible in the CaII H maps. At Hα line center and wings, the power of the oscillations has a fibrilar structure around network bright points. Hα ±0.35 Å D.S. and Hα line center (to a lesser extent) show power suppression (magnetic shadow, see Judge et al. (2001)) of the 3 min and 5 min oscillations. Hα ±0.7 Å D.S., which samples lower heights (upper photosphere), shows power enhancement (power halo, see Krijger et al. (2001)) at 3 min and 5 min. 7 min power is enhanced at the network in both Hα center and wings.

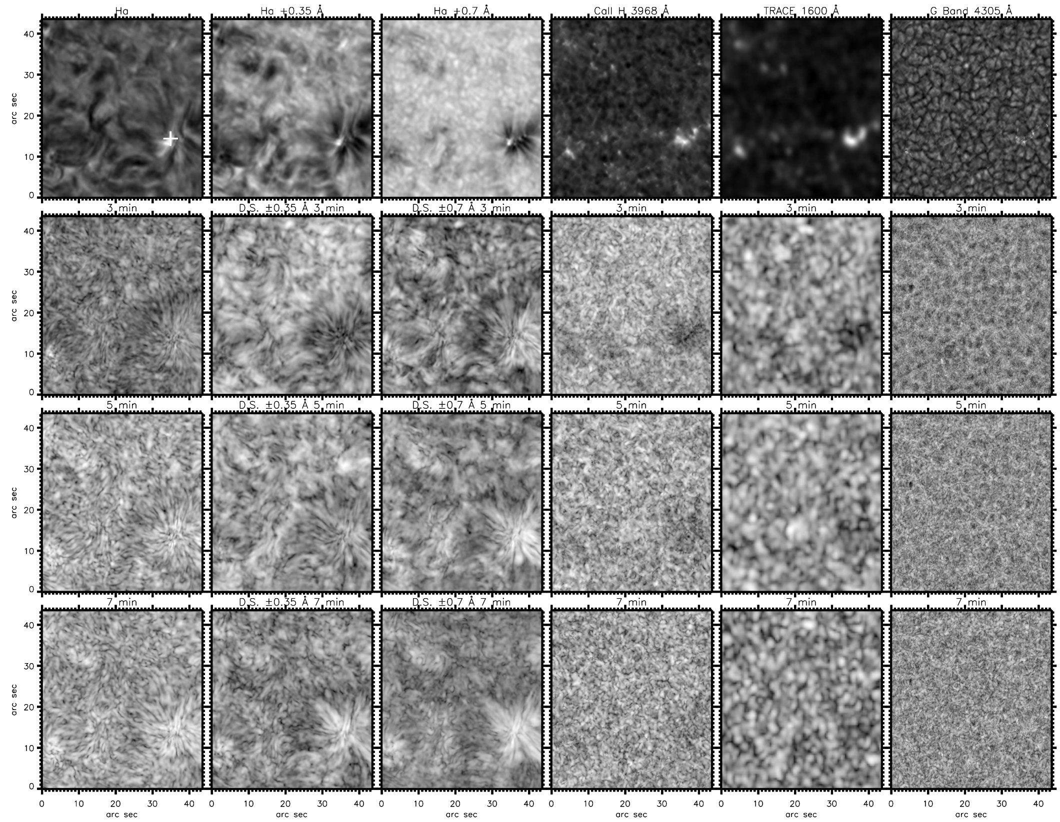

Figure 1. *Top row:* Average intensity images of our observations. *Second, third and fourth rows:* Respective average global wavelet power maps at 3 min, 5 min and 7 min.

To gain further insight on the variation of oscillatory power in network and internetwork we use the following technique: We calculate the average power over expanding concentric circles, centered on the NBP cluster center which is marked with a white cross on the first panel of Fig. 1. This azimuthally averaged power, as a function of distance from the network, is shown in Fig. 2, for 3, 5 and 7 min oscillations, calculated for all filters and band-passes.

The power suppression at 3 min is shown by the decreased power at all chromospheric heights (TRACE continua, CaII H, Hα line center and Hα ±0.35 Å D.S.). The distance at which the 3 min oscillatory power reaches internetwork

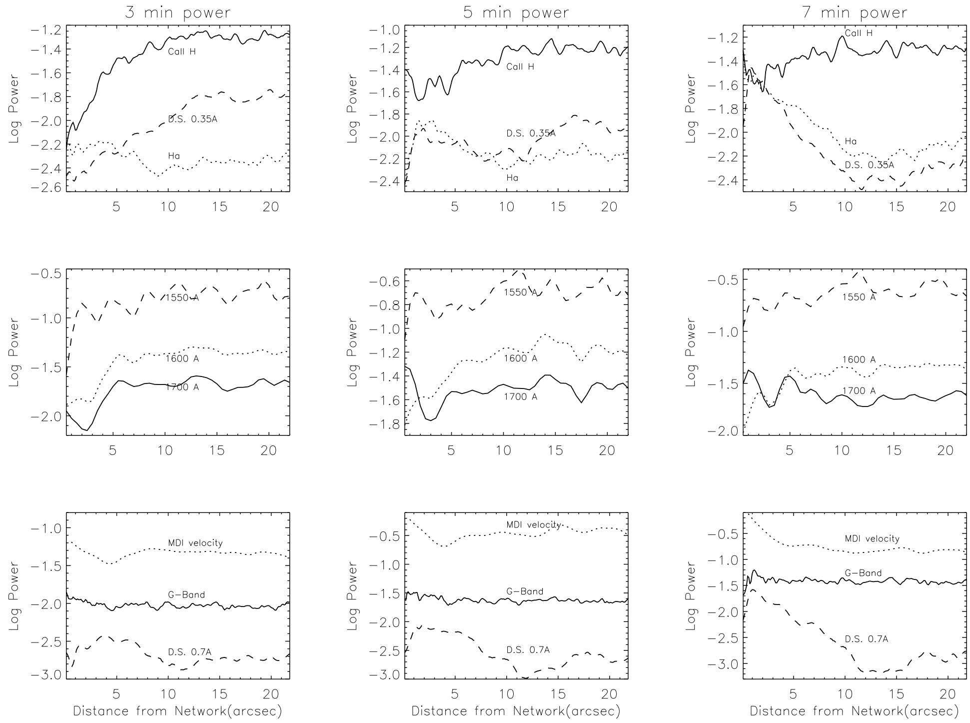

Figure 2. Azimuthally averaged power, over concentric circles around the center of the NBP cluster, marked with the white cross in Fig. 1 (see text). 3, 5 and 7 min average power is plotted in columns 1,2 and 3 respectively while each row refers to bandpasses at photospheric (bottom), mid chromospheric (middle) and chromospheric heights (upper row). Internetwork is safely assumed to be at distances greater or equal than $10''$.

(located at distances greater than $10''$) values varies with height. This depicts the fact that the extent of the area which the magnetic field affects varies as well with height. At the photosphere we find increased power at all period bands, near the NBP, at the G–band, at the MDI velocity and Hα ± 0.7 Å D.S. This is probably the manifestation of a power halo, also reported for active regions (e.g. Brown et al. (1992), Muglach et al. (2005)) The 7 min power observed at Hα levels is attributed to the presence of mottles. It is increased over locations of mottles and decreases critically at the internetwork. Interestingly, there seems to be a 7 min signature near NBPs at the TRACE continua power maps. Mottles are probably sampled by TRACE but are not visible due to lack of spectral resolution. There are similarities in the variation of power between the TRACE UV bands. 1600 Å and 1700 Å pass-bands are formed more or less at the same height but the 1550 Å one contains contributions from much higher layers, thus it differs systematically from the other two. There are indications that power variations at the TRACE continua contain contributions from CaII H and Hα levels. This is quite possible in fact, since the UV continua span a large height range in the atmosphere and contain UV continuum plus several emission lines. The remarks made above will be further explored in the future.

2. Discussion

We have presented results on the oscillatory behavior of the atmospheric layers and its variation in respect with the magnetic topology i.e. the distinction in network and internetwork. In general, in the internetwork atmosphere, which is devoid of strong magnetic fields, the gas pressure dominates its dynamics. This situation gradually changes at higher layers where gas pressure decreases and the expanding magnetic flux tubes result to increased magnetic pressure. The plasma-β parameter, (the ratio of gas to magnetic pressure) is used to describe the different domains of the solar atmosphere, which is divided in high and low β domains. In the former, acoustic oscillations, generated by the granular motions, propagate but they may undergo mode conversion, reflection or refraction when they meet low β conditions (see e.g. Rosenthal et al. (2002), Bogdan et al. (2003)).

The expanding flux tubes of the network bright points provide such critical boundaries, onto which acoustic oscillations transform into magnetoacoustic ones and reflect or refract. The reflected waves probably result to the increased acoustic power observed at the photospheric levels around the network (power halos, seen in our MDI, G–Band and Hα $\pm$0.7 Å D.S. 3 min and 5 min power maps) while the inhibition of the same oscillations at chromospheric levels results to reduced power above and around the magnetic concentrations of the chromospheric network (magnetic shadow, observed at our TRACE, CaII H, Hα and Hα $\pm$0.35 Å D.S. 3 min and 5 min power maps).

This mechanism is supported by our findings. While it has been widely accepted that the magnetic field affects drastically the propagation of acoustic oscillations, our results show that chromospheric mottles, which outline the diverging magnetic field lines, maybe the specific locations where the above described mode transformations occur. Increased 7 min power near network boundaries in TRACE continua power maps is evidence for a possible mottle signature in the oscillatory profile of the TRACE UV continua. Further investigation of the interconnection between the different atmospheric layers in terms of wave propagation, from the photosphere to the corona and interaction with the fine structure and the local magnetic fields is under way.

Acknowledgments. The DOT is operated by Utrecht University at the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias. The authors thank P. Sütterlin for the observations and R. Rutten for the data reduction. We are grateful to the SoHO and TRACE science planning teams.

References

Bogdan, T. J., Carlsson, M., Hansteen, V., et al. 2003, ApJ, 599, 626
Brown, T. M., Bogdan, T. J., Lites, B. W., & Thomas, J. H. 1992, ApJ, 394, L65
Judge, P.G., Tarbell, T.D., Wilhelm, K. 2001, ApJ, 554, 424
Krijger, J. M., Rutten, R. J., Lites, B. W. et al. 2001, A&A, 379, 1052
Muglach, K., Hofmann, A., Staude, J. 2005, A&A, 437, 1055
Rosenthal, C. S., Bogdan, T. J., Carlsson, M., et al. 2002 ApJ, 564, 508
Rutten, R. J., Hammerschlag, R. H., Bettonvil, F. C. M. et al. 2004, A&A, 413, 1183
Torrence, C., & Compo, G.P. 1998, Bull. Amer. Meteor. Soc., 79, 61